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FORAGES

Nutritive Quality of Cool-Season Grass Monocultures and Binary Grass–Alfalfa Mixtures at Late Harvest

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ABSTRACT

Nutritive quality of hay is compromised when harvest is delayed, but reproduction of upland nesting birds in the northern Great Plains would be improved if haying operations could be deferred until mid-July or later to allow completion of nesting. This study was conducted to determine nutritive quality of hay at a single mid-July cutting from three cool-season grass species that were grown in monoculture and in binary mixtures with alfalfa [*Medicago sativa* subsp. × *varia* (Martyn) Arcang.] near Mandan, ND. Grasses were intermediate wheatgrass [*Thinopyrum intermedium* (Host) Barkw. & Dewey], smooth bromegrass (*Bromus inermis* Leyss.), and crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.]. Annual applications of 0 and 50 kg N ha^{-1} had no effect on in vitro dry matter digestibility (IVDMD) or neutral detergent fiber (NDF) levels of grass or alfalfa. Grass monocultures and alfalfa averaged 612 and 624 g kg^{-1}, respectively, for IVDMD and 651 and 567 g kg^{-1} , respectively, for NDF. At 0 kg N ha^{-1}, crude protein (CP) ranged from 71 to 78 g kg^{-1} in grass monocultures and from 92 to 131 g kg^{-1} in grass–alfalfa mixtures. At 50 kg N ha^{-1}, CP ranged from 83 to 97 g kg^{-1} in grass monocultures and from 99 to 133 g kg^{-1} in mixtures. Feasibility of deferring hay harvest to allow reproduction of upland nesting birds in the northern Great Plains depends on maintaining alfalfa or other legumes with high nutritive quality in grass mixtures to reduce NDF and increase CP levels.

Haying operations in the northern Great Plains often destroy nests, eggs, and incubating hens of upland nesting ducks (*Anas* spp.) and pheasants (*Phasianus colchicus* L.) (Kirsch et al., 1978). Nesting success of waterfowl, pheasants, and other upland nesting birds would be greatly improved if haying were delayed from mid-June to mid-July or later. A 17-yr study in North Dakota documented that 78% of duck nests hatch by 20 July (Higgins et al., 1992). Options may exist to obtain hay of adequate nutritional value for beef cattle at a deferred cutting date. Boe et al. (1998) reported that yellow-flowered alfalfa [*M. sativa* subsp. *falcata* (L.) Arcang.] was adapted to a mid- to late-July single cutting for hay in the northern Great Plains. Adaptation to delayed harvest is due to an indeterminate growth habit that provides new vegetative growth over the season and to relatively low levels of leaf yellowing and stunting caused by potato leafhopper (*Empoasca fabae* Harris) feeding.

The decline in nutritive quality of forages with advancing stages of plant development is well documented (Kalu and Fick, 1981; Albrecht et al., 1987; Buxton and Marten, 1989). It has also been well established that digestibility and protein decline more slowly in alfalfa leaves than in stems as the crop matures (Kilcher and Heinrichs, 1974; Kalu and Fick, 1983; Buxton et al., 1985). Kilcher and Heinrichs (1974) reported that digestible energy of alfalfa leaves averaged approximately 700 g kg^{-1} and CP approximately 230 g kg^{-1} at the late-bloom stage of development. Provided leaf loss was minimal, they concluded that alfalfa quality at late bloom was adequate for all classes of beef cattle, that dry matter yield continued to increase until late bloom, and that delaying harvest to this stage of development would have no great disadvantage in prairie regions where only one cutting was usually feasible. They did note, however, that hot, dry winds under semiarid prairie conditions can cause rapid leaf shedding and did not recommend delayed harvest past midbloom, which would occur before nesting is completed for most upland nesting birds.

Advantages of grass–legume mixtures over grass monocultures have been attributed to greater stand longevity (Drolsom and Smith, 1976), higher nutritive quality (Sleugh et al., 2000), and higher total forage yield (Baylor, 1974). Comparing unfertilized plots in the sixth year after seeding, Berdahl et al. (2001) found that the four binary grass–alfalfa mixtures included in the present study averaged twofold higher dry matter yields than the four

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Abbreviations: CP, crude protein; IVDMD, in vitro true dry matter digestibility; NDF, neutral detergent fiber.

grass entries grown in monoculture when N fertilizer was not applied. The grass entries were 'Reliant' (Berdahl et al., 1992) and 'Manska' (Berdahl et al., 1993) intermediate wheatgrass, 'Lincoln' smooth bromegrass (Hein, 1955a), and 'Nordan' crested wheatgrass (Hein, 1955b). Grass grown in association with a legume for hay will reduce dry-down time compared with legume monocultures and improve hay-handling properties. The benefit of improved cultivars of intermediate wheatgrass in grass–alfalfa mixtures for hay has been reported in studies by Sleugh et al. (2000) and Berdahl et al. (2001).

The objective of this study was to determine nutritive quality of hay from four grass monocultures and their respective binary mixtures with alfalfa at a single mid-July cutting under two levels of N fertility. The mid-July cutting would allow time for most upland nesting birds to complete their nesting.

MATERIALS AND METHODS

Field Plots

The test was sown 26 May 1993 at a dryland site near Mandan, ND, on a Parshall fine sandy loam soil (coarse-loamy, mixed, superactive, frigid, Pachic Haplustolls). Four grass cultivars were sown in monoculture and in binary mixtures with 'Rangelander' alfalfa, a cultivar noted for long-term persistence in the Prairie Provinces of Canada and possessing a moderately indeterminate growth habit similar to many yellow-flowering alfalfa accessions (Heinrichs et al., 1979). All four grass cultivars are commonly grown for hay in monoculture and in mixtures with alfalfa in the northern Great Plains. Treatments were in a split-plot arrangement with four replicates, using a randomized complete block design. Whole plots, also referred to as management practices, were a factorial combination of grass monocultures or binary grass–alfalfa mixtures (hereafter referred to as mixtures) and N (NH_4NO_3) rates of 0 or 50 kg N ha^{-1} broadcast annually in April. Subplot treatments consisted of Reliant intermediate wheatgrass, Manska intermediate wheatgrass, Lincoln smooth bromegrass, and Nordan crested wheatgrass and their respective mixtures with alfalfa. Each subplot consisted of three rows 6.1 m long with a 38-cm row spacing. Seeding rate was 100 pure live seeds per lineal meter of row. Mixtures were 65% grass by seed count. A single row of crested wheatgrass was sown between each plot to control intermingling of rhizomatous grasses from adjacent plots. Other details of management practices and precipitation patterns are provided in a paper dealing with dry matter yields of these plant materials (Berdahl et al., 2001).

Forage Quality

In vitro true dry matter digestibility (IVDMD), NDF, and CP were measured on individual subplots at a mid-July cutting in 1994 and 1995 when alfalfa was at the late-bloom to early-pod stage of development. Plants were cut to a stubble height of approximately 8 cm. Grass and alfalfa components from each mixture subplot were hand-separated for the entire subplot, and quality traits were measured on unmixed grass and alfalfa subsamples. Dry weight ratios of grass/alfalfa in subplots were used to weight measurements of each quality trait and to calculate overall concentrations for mixture subplots. Subsamples for forage quality measurements were dried at 60°C and ground in a shear mill to pass a 1.0-mm screen. In vitro true dry matter digestibility and NDF were determined according to modifications of the procedures of Goering and Van Soest (1970). Neutral detergent fiber in forage samples and the residue remaining after a 48-h in vitro fermentation for IVDMD were determined in an ANKOM Fiber Analyzer (ANKOM Technol., Fairport, NY) using neutral detergent solution that did not contain amylase or sodium sulfite. In vitro fermentations for IVDMD were conducted in an ANKOM Daisy II Rumen Incubator according to procedures described by Vogel et al. (1999). Nitrogen was measured using a N-C-S analyzer (Carlo Erba Model NA 1500 Series 2, CE Elantech, Inc., Lakewood, NJ). Samples from both years were included in a single run for measurement of each quality trait.

Data Analysis

Management practices, i.e., whole plots (grass monocultures and mixtures at 0 and 50 kg N ha^{-1}) and subplots (grass cultivars), were considered as fixed effects, and years were considered as random effects in a third split in a combined split-plot analysis over years (Steel and Torrie, 1980). Whole-plot effects for IVDMD, NDF, and CP were partitioned into the following single degree-of-freedom comparisons: grass monocultures vs. grass–alfalfa mixtures, 0 vs. 50 kg N ha^{-1}, and species makeup (monocultures or mixtures) × N fertility level. Independent *t* tests of individual plot values were used to compare IVDMD, NDF, and CP at the two N fertility levels for grass in monocultures, grass–alfalfa mixtures, and comparisons with grass and alfalfa components of mixtures. Comparisons of grass percentage in mixtures were based on an analysis with whole plots consisting of only the grass–alfalfa mixtures at 0 and 50 kg N ha^{-1}. Comparisons within the grass or alfalfa component of mixtures were based on separate split-plot analyses involving fertilizer treatments (whole plots), cultivars (subplots), and years (sub-subplots) for each component. Comparisons among cultivar effects within whole plots were made using a protected least significant difference test at $P \leq 0.05$ ($LSD_{0.05}$). Statistical analyses (PROC GLM and PROC TTEST) were conducted using SAS procedures (SAS Inst., 1990).

RESULTS AND DISCUSSION

Grass and Alfalfa Proportions in Mixtures

Nitrogen fertilizer level × year and cultivar × year interaction effects were significant ($P \leq 0.05$) for percentage grass in grass–alfalfa mixtures. Nitrogen fertilizer increased the proportion of grass in the mixtures significantly ($P \leq 0.05$) in 1995 but not in 1994 (Table 1). By the second production year, grasses with rhizomatous growth habit were strongly dominant over alfalfa when N was applied at 50 kg ha^{-1}. Wedin et al. (1965),

Table 1. Percentage grass by weight in binary grass–alfalfa mixtures receiving 0 and 50 kg N ha^{-1} in 1994 and 1995.

Grass component†	1994		1995	
	0 kg N ha^{-1}	50 kg N ha^{-1}	0 kg N ha^{-1}	50 kg N ha^{-1}
Reliant IWG	67a‡	69a	83a	91a
Manska IWG	66a	69a	74b	93a
Lincoln SB	38b	51b	49c	81b
Nordan CWG	20c	31c	24d	47c
Mean	48A§	55A	57B	78A
Std. error	3.7	2.9	3.9	2.0

† IWG, intermediate wheatgrass; SB, smooth bromegrass; CWG, crested wheatgrass.

‡ Means within a column that are followed by the same lowercase letter are not significantly different according to an $LSD_{0.05}$.

§ Means for N levels within each year are not significantly different if followed by the same uppercase letter.

Kilcher (1966), Nuttall et al. (1991), and others have also reported that N fertilizer stimulates the grass component of grass–alfalfa mixtures. Crested wheatgrass, shortest in stature and the only bunchgrass included in the study, had lower composition in mixtures than the other grass species (Table 1). The single annual cutting in mid-July appeared to favor the three rhizomatous grass entries over alfalfa. Sheaffer et al. (1997) also reported grass dominance in mixtures that were either left uncut or cut only once per year late in the growing season. Cultivar effects and cultivar × management practice interaction effects accounted for much of the variation in the forage quality traits IVDMD, NDF, and CP. Management practice × year interaction effects for NDF and CP were due in large part to changes in percentage grass in mixtures from one year to the next.

In Vitro Dry Matter Digestibility

Crested wheatgrass, the earliest-maturing grass in this study, had lower IVDMD than the other grass entries (Table 2). At the mid-July cutting date, crested wheatgrass seed heads were mature, smooth bromegrass was at the hard-dough stage of seed maturity, and intermediate wheatgrass was at soft dough. Crested wheatgrass monocultures as well as the crested wheatgrass component of mixtures had lower IVDMD than the alfalfa component ($P \leq 0.05$; independent *t* test), but IVDMD of the other grasses was approximately equal to alfalfa. A significant ($P \leq 0.05$) cultivar × N level interaction can be accounted for by the lower proportion of grass in mixtures containing crested wheatgrass than in the other cultivar mixtures (Table 1). This resulted in relatively high IVDMD in crested wheatgrass mixtures compared with crested wheatgrass monocultures (Table 2). Averaged over the four cultivars, mixtures were not significantly higher in IVDMD than grass monocultures, and N fertility level had no effect on IVDMD.

Neutral Detergent Fiber

Neutral detergent fiber is composed of cell walls and includes cellulose, hemicellulose, lignin, and heat-damaged protein (Van Soest, 1982). Neutral detergent fiber is associated with bulkiness of hay and is related to forage intake. The grass component of all mixtures had higher ($P \leq 0.05$; independent *t* test) NDF concentration than the alfalfa component (Table 2). Averaged over the four cultivars, mixtures were significantly ($P \leq 0.01$; independent *t* test) lower in NDF than grass monocultures when no N fertilizer was applied. The difference in NDF between mixtures and monocultures was not significant at the 50 kg N ha^{-1} fertilizer rate due to high amounts of grass in the mixtures, particularly during the second production year (Table 1). Grass–alfalfa mixtures had a greater increase in NDF from 1994 to 1995 than grass monocultures due to large increases in grass in mixtures during the second production year. This resulted in a significant ($P \leq 0.05$) management practice × year interaction effect for NDF. As expected, crested wheatgrass, with its early maturity, had higher NDF than the other grass entries when grown in monoculture. Crested wheatgrass mixtures had the lowest NDF concentration due to a higher proportion of alfalfa

Table 2. In vitro dry matter digestibility (IVDMD) values and concentrations of neutral detergent fiber (NDF) and crude protein (CP) in binary grass–alfalfa mixtures and grass monocultures receiving 0 and 50 kg N ha^{-1} and cut at late-bloom to early-pod stage in 1994 and 1995.

	Binary mixtures							
Grass cultivars and species†	Grass component		Alfalfa component		Grass–alfalfa mixture		Grass monocultures	
	0 kg N ha^{-1}	50 kg N ha^{-1}	0 kg N ha^{-1}	50 kg N ha^{-1}	0 kg N ha^{-1}	50 kg N ha^{-1}	0 kg N ha^{-1}	50 kg N ha^{-1}
	g kg^{-1}							
				IVDMD				
Reliant IWG	621a‡	617a	625	638	622a	622	624ab	611b
Manska IWG	626a	624a	614	624	623a	624	646a	632a
Lincoln SB	612a	621a	626	624	618ab	622	604bc	613ab
Nordan CWG	566b	570b	620	623	603b	606	581c	579c
Mean	606A§	608A	621A	627A	617A	619A	614A	609A
Std. error	6.4	5.5	6.0	7.7	3.9	3.3	9.0	7.9
				NDF				
Reliant IWG	647b	645b	548b	571	622a	631a	647b	645ab
Manska IWG	655b	635b	579a	578	633a	625a	652b	641b
Lincoln SB	656b	645b	553b	579	597b	624a	651b	643b
Nordan CWG	672a	668a	561ab	565	585b	606b	667a	657a
Mean	658A	648A	560A	573A	609A	622A	654A	647A
Std. error	5.6	6.3	9.4	7.5	4.9	5.2	7.6	8.8
				CP				
Reliant IWG	77c	84c	146b	151	92c	99b	73	83
Manska IWG	82bc	90bc	144b	149	96c	103b	78	86
Lincoln SB	86b	105a	155a	150	116b	125a	74	97
Nordan CWG	94a	97ab	148ab	149	131a	133a	71	93
Mean	85A	94A	148A	150A	109A	115A	74B	90A
Std. error	2.4	3.3	4.3	4.0	2.3	2.9	2.6	2.8

† IWG, intermediate wheatgrass; SB, smooth bromegrass; CWG, crested wheatgrass.

‡ Means in a column within each management practice and nutritive quality component that are followed by the same lowercase letter are not significantly different according to an $LSD_{0.05}$.

§ Fertilizer treatments averaged over cultivars and years are not significantly different ($P \leq 0.05$) when mixture or monoculture means are followed by the same uppercase letter according to independent *t* tests of individual plot means.

in crested wheatgrass mixtures than the other grass mixtures (Tables 1 and 2). Intermediate wheatgrass mixtures had relatively high NDF concentrations due to low amounts of alfalfa. However, the cultivar × management practice interaction was not significant.

Crude Protein

Crude protein of crested wheatgrass and smooth bromegrass monocultures increased more in response to N fertilizer than the two intermediate wheatgrass cultivars and accounted for a significant ($P \leq 0.05$) cultivar × management practice interaction (Table 2). Crude protein of the alfalfa component of grass mixtures did not respond to application of 50 kg N ha^{-1}, but alfalfa was consistently higher ($P \leq 0.01$; independent *t* test) in CP than grass monocultures and the grass component of mixtures. Grass composition of mixtures increased in response to N fertilizer, particularly in the second production year (Table 1). As a result, CP concentration of mixtures receiving 50 kg N ha^{-1} decreased more from the first to the second production year than CP of mixtures that received no N fertilizer, accounting for a significant ($P \leq 0.05$) management practice × year interaction. At 0 kg N ha^{-1}, the grass component of mixtures was higher ($P \leq 0.05$; independent *t* test) in CP than grass monocultures, but at 50 kg N ha^{-1}, CP of grass in mixtures was not different from monocultures (Table 2). Averaged over the four cultivars, mixtures were significantly higher ($P \leq 0.01$; independent *t* tests) in CP concentration than grass monocultures at both the 0 and the 50 kg N ha^{-1} fertilizer rates. At 0 kg N ha^{-1}, hay from all the mixtures was in excess of the 86 to 89 g kg^{-1} CP concentration that is required for pregnant dry cows during the last 2 mo before calving (Natl. Res. Counc., 1996). In contrast, none of the grass monocultures provided adequate CP at 0 kg N ha^{-1}, and intermediate wheatgrass receiving 50 kg N ha^{-1} was only marginal in CP concentration for cows just before calving and clearly inadequate for lactating cows.

Management Implications

Although hay quality is compromised with delayed harvest, grass–alfalfa mixtures included in this study would provide beef cow-calf producers in the northern Great Plains with the option to defer hay harvest until mid-July and meet the nesting requirements of most waterfowl and upland game birds when bird reproduction is of economic or aesthetic importance. Intermediate wheatgrass is recommended over smooth bromegrass and crested wheatgrass to provide tall, dense cover for nesting (Duebbert et al., 1981). To avoid the expense of N fertilizer, alfalfa is needed in a mixture of intermediate wheatgrass to maintain dry matter yield (Berdahl et al., 2001) and, at delayed harvest, provide adequate protein concentration (Table 2). Intermediate wheatgrass became highly dominant over alfalfa in our study when hay harvest consisted of a single mid-July cutting. Earlier cutting and, if regrowth is adequate, multiple cuttings would be needed in some years to maintain a favorable balance of intermediate wheatgrass and alfalfa in a mixture. We found that intermediate wheatgrass and alfalfa were of nearly equal proportion in these plots after a single year with a two-harvest, mid-June and mid-August cutting (Berdahl et al., 2001). Duebbert et al. (1981) reported that greater duck nest densities and higher hatch rates were usually found in relatively large, uninterrupted nesting areas that exceeded 16 ha. This requirement of scale for nesting areas would likely apply to reproductive success of other upland nesting birds as well. If cutting schedules need to be varied from one year to the next to maintain a proper balance of intermediate wheatgrass and alfalfa, then the practice of deferred hay harvest to provide effective nesting areas consistently over a long-term period would require relatively large blocks of land. Deferring hay harvest and the accompanying management needed to maintain a favorable balance of grass and alfalfa in mixtures are practices that could not be done on a sufficiently large scale to accommodate bird nesting and reproduction on many small hobby farms and ranches.

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